Science of the Total Environment 550 (2016) 418–430

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Spatial and temporal variability of snow chemical composition and accumulation rate at Talos Dome site (East Antarctica)

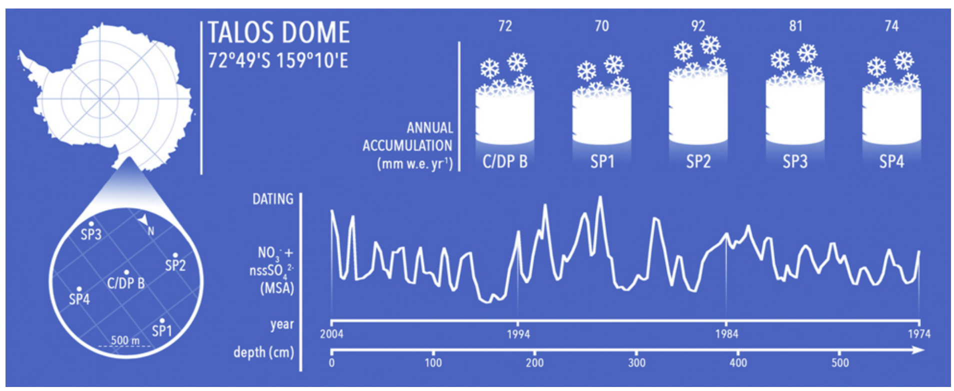
Laura Caiazzo, Silvia Becagli, Daniele Frosini, Fabio Giardi, Mirko Severi, Rita Traversi *, Roberto Udisti

Department of Chemistry "Ugo Schiff", Via della Lastruccia 3, I-50019, Sesto F.no (Florence), Italy

HIGHLIGHTS

- Firn core decontamination is proved to be efficient for all the ions except ammonium.
- Post-depositional storage effects are found for MSA, NO_3^-, NH_4^+.
- Relatively high accumulation rate allows preservation of nitrate and MSA.
- Undisturbed deposition allows annual snow layer counting by NO_3^-, $nssSO_4^{2-}$ and MSA.
- Spatial variability is lower than temporal variability at 5% significance level.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 16 October 2015
Received in revised form 13 January 2016
Accepted 14 January 2016
Available online 2 February 2016

Editor: D. Barcelo

Keywords:
Ion species
Snow layer
Talos Dome
Spatial variability
Accumulation rate

ABSTRACT

Five snow pits and five firn cores were sampled during the 2003–2004 Italian Antarctic Campaign at Talos Dome (East Antarctica), where a deep ice core (TALDICE, TALos Dome Ice CorE, 1650 m depth) was drilled in 2005–2008 and analyzed for ionic content.

Particular attention is spent in applying decontamination procedures to the firn cores, as core sections were stored for approximately 10 years before analysis. By considering the snow pit samples to be unperturbed, the comparison with firn core samples from the same location shows that ammonium, nitrate and MSA are affected by storage post-depositional losses. All the other measured ions are confirmed to be irreversibly deposited in the snow layer. The removal of the most external layers (few centimeters) from the firn core sections is proved to be an effective decontamination procedure.

High-resolution profiles of seasonal markers (nitrate, sulfate and MSA) allow a reliable stratigraphic dating and a seasonal characterization of the samples. The calculated mean accumulation-rate values range from 70 to 85 mm w.e. $year^{-1}$, in the period 2003–1973 with small differences between two sectors: 70–74 mm w.e. $year^{-1}$ in the NNE sector (spanning 2003–1996 years) and 81–92 mm w.e. $year^{-1}$ in the SSW sector (spanning 2003–1980 years). This evidence is interpreted as a coupled effect of wind-driven redistribution processes in accumulation/ablation areas.

Statistical treatment applied to the concentration values of the snow pits and firn cores samples collected in different points reveals a larger temporal variability than spatial one both in terms of concentration of chemical markers and annual accumulation.

* Corresponding author.
E-mail address: rita.traversi@unifi.it (R. Traversi).

http://dx.doi.org/10.1016/j.scitotenv.2016.01.087

The low spatial variability of the accumulation rate and chemical composition measured in the five sites demonstrates that the TALDICE ice core paleo-environmental and paleo-climatic stratigraphies can be considered as reliably representative for the Talos Dome area.

1. Introduction

Ice cores drilled in unperturbed deposition areas represent a unique archive of the composition of past atmospheres. Obtaining chemical, isotopic and physical ice core stratigraphies allows reconstructing past environmental and climatic changes on time scales ranging from a few decades to hundreds of thousands of years (e.g., EPICA Community Members, 2004, 2006).

In the framework of the IPICS (International Partnerships in Ice Core Sciences) program, the Talos Dome site (East Antarctica) was chosen for a deep ice core drilling (TALDICE Project). The main goal of the TALDICE project was to obtain high-resolution chemical, isotopic and physical stratigraphies in an East Antarctic site located not far from the coast and characterized by a relatively high accumulation rate of about 80 mm water equivalent per year (here-hence w.e. year^{-1}) as average 2004–1259 AD (Stenni et al., 2002). These features, together with its position on a geographical dome, are believed to allow reconstruction of the environmental and climatic changes occurring in the Ross Sea–Wilkes Land coast marine sector for the last 200 kyear and to allow a comparison of such stratigraphies with those obtained from the EPICA-Dome C and Taylor Dome ice cores (Bianchi et al., 2003; Frezzotti et al., 2004; Urbini et al., 2006). TALDICE drilling (2005–2008) reached the depth of 1650 m, covering the last 250 kyear (Bazin et al., 2013; Veres et al., 2013). The TALDICE ice core revealed that the Talos Dome site is very sensitive to the climatic variations occurring at regional-to-global scale over the last climate cycle (Stenni et al., 2011). Particular attention was paid to changes in marine and atmospheric circulation and marine productivity in the Ross Sea and Adelie Land sectors (Scarchilli et al., 2011). Its relatively large accumulation rate (with respect to other ice core sites located on the Antarctic Plateau) enables an accurate dating of the core, particularly during the Holocene (the last 11.5 kyear) and the last climatic transition (Buiron et al., 2011).

In order to assess the reliability of the achieved stratigraphic records from a certain site, the site variability needs to be studied by comparing chemical and accumulation data series from snow pits and firn cores sampled in different points.

In particular, the spatial variability should be compared with the temporal variability in order to verify whether the observed temporal changes can be reliably associated to actual environmental or climatic changes or to site variability.

Previous samplings (by snow pits and shallow firn cores) were carried out around Talos Dome area (Becagli et al., 2004, 2005; Benassai et al., 2005; Frezzotti et al., 2005; Sala et al., 2008; Severi et al., 2009) but the sampling sites were distributed in a large area and the sampling strategy was not specifically addressed to evaluate the spatial variability of the TALDICE drilling site.

Aiming to contribute to a better interpretation of the TALDICE stratigraphies and to assess the spatial variability of the Talos Dome area, the samples collected in five snow pits and five firn cores are analyzed evenly distributed at a short distance from the TALDICE site. One site was chosen in the same TALDICE site, and the others at a distance of approximately 500 m along the North, South, West, East cardinal directions.

The sampling was carried out during the 2003–2004 Italian Antarctic Campaign, but chemical analysis was not immediately performed. Snow pit and firn core samples have been analyzed for the ion content (inorganic anions and cations and selected organic anions) in 2013–2014.

The main goal of this paper is evaluating the spatial variability of the snow chemical composition and accumulation rate close to the main drilling site and assessing if the TALDICE deep ice core stratigraphies can be considered as reliably representative of the Talos Dome deposition area.

A secondary goal is to evaluate the effects of a long-time storing of firn core sections (about 10 years) on the preservation of the original chemical signatures. For this purpose, a decontamination procedure is applied in order to eliminate a possible contamination of the external snow layers of the firn core sections and the effects of possible post-depositional processes are tested by comparing homologous (same site, similar depth) firn core and snow pit samples.

2. Methodology

2.1. Sampling site

Talos Dome (72°48′S, 159°06′E; 2316 m a.s.l.) is an about 900 km^2 elliptical ice dome, elongated in a NW–SE direction (perpendicular to the prevalent wind direction — Urbini et al., 2008), in Northern Victoria Land, at the edge of the East Antarctic plateau. It is located at about 290 km from the Southern Ocean (Oates Land–George V Land), 250 km from the Ross Sea, and 275 km from the Italian Mario Zucchelli Station (Terra Nova Bay) (Fig. 1).

The site is characterized by an annual mean temperature (as recorded at 15 m depth) of −41 °C, and by an annual snow accumulation of about 80 mm w.e. year^{-1}, evaluated over the 1217–1996 AD period (Stenni et al., 2002). Because of the relatively high accumulation rate, ice cores drilled at this site are considered to be suitable for high-resolution records of past environmental and climatic variations.

Five snow pits were dug and five shallow firn cores were drilled during the 2003–2004 Italian Antarctic Campaign. Table 1 reports the basic geographical and glaciological information on the sampling sites.

The snow pits were dug by hand and the samples were collected by inserting pre-cleaned polyethylene vials along a vertical line in the snow wall. During the sampling, particular care was paid in minimizing contamination risk: the pit wall was cleaned by a pre-cleaned stainless steel scraper and personnel wore sterile clothing and polyethylene gloves. The sample depth resolution is 3 cm (external diameter of the vials).

The snow density was measured by inserting a double-side open stainless steel cylinder (whose internal volume is known) every 10 cm into the snow wall. The recovered snow volume was stored in a plastic bag and weighed the same sampling day in a cold laboratory. The mean density is 0.37 g/cm^3 (Severi et al., 2009).

The vials containing the samples were stored in sealed polyethylene bags and kept frozen in insulated boxes for transport to Italy (Severi et al., 2009).

At every site, a shallow firn core was also drilled, in order to increase the sampling depth. The firn core sections were stored in sealed polyethylene bags and kept frozen in insulated boxes for transport to Italy.

2.2. Sampling procedures and analysis

Unlike snow pit samples, for which the contamination risk is quite low once the wall of the pit has been carefully cleaned and clean vials were used to collect and store the samples, firn core sections can undergo serious contamination risks. Contamination can originate from the firn core sampler and from the handling of the firn core sections during